Variations of the chemical composition of five coastal catch fish species of the Gulf of Gabès (Tunisia)

by

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ABSTRACT. - The aim of this work is to study the variation of the global chemical composition of five fish species of the coastal catch from the Gulf of Gabès: *Diplodus annularis* (L., 1758), *Zosterisessor ophiocephalus* (P., 1811), *Liza aurata* (R., 1810), *Caranx rhonchus* (G., 1817) and *Boops boops* (L., 1758). The moisture, protein, fat and ash content variations according to sex, size, organs and meat parts of the muscle were examined. The muscle meat parts composition shows large variation between these species namely as regards moisture and fat contents. Fat content decreases from head to tail. The fish species and the position in fish body are the main factors explaining the variability of the muscle moisture content. Negative correlations between fat and moisture contents were observed in all species. The discriminant analysis of moisture, proteins, fat and ash contents measured in the muscles allowed the distinction of different fish groups according to their global chemical compositions.

RÉSUMÉ. - Variation de la composition chimique globale de cinq espèces de poissons de la pêche côtière du golfe de Gabès (Tunisie).

Ce travail porte sur l'étude de la variation de la composition chimique globale de cinq espèces de la pêche côtière du golfe de Gabès : *Diplodus annularis* (L., 1758), *Zosterisessor ophiocephalus* (P., 1811), *Liza aurata* (R., 1810), *Caranx rhonchus* (G., 1817) et *Boops boops* (L., 1758). La variation des constituants chimiques (eau, protéines, lipides et cendres) a été examinée selon les espèces et en fonction de la localisation des régions du corps, de la taille et du sexe. Les parties de la chair présentent des variations selon les espèces. Ces variations sont importantes pour l'eau et les lipides et moins importantes pour les protéines et les cendres. Les teneurs en lipides montrent la présence d'un gradient antéropostérieur décroissant dans la chair des poissons. Les principaux facteurs expliquant la variabilité de la teneur en eau dans le muscle sont l'espèce et les régions du corps. Des corrélations négatives entre les teneurs en eau et en lipides ont été observées pour les différentes espèces. L'analyse discriminante a permis de distinguer différents groupes parmi les espèces étudiées, en fonction de leurs compositions chimiques.

Key words. - *Diplodus annularis* - *Zosterisessor ophiocephalus* - *Liza aurata* - *Caranx rhonchus* - *Boops boops* - MED - Tunisia - Coastal catch fish - Chemical composition - Muscle - Sex - Size.

The fishery sector plays an important socioeconomic role in coastal countries. The world production of fishes and invertebrates is approximately 100 million tons annually. The average human consumption of fish is about 12 kg/person annually. In Tunisia, the halieutic production was estimated to 70,825 tons in 2008 and the coastal catch was about 15,710 tons (DGPA, 2008). This coastal catch is witnessing a noticeable reduction since it decreased from 27626 tons in 1995 to 15,710 tons in 2008. As the fish stock tends to decrease, this natural food reserve should be preserved from contamination by toxic products as well as industrial waste. Moreover, the period, the quantity and the size of the catch should be seriously respected.

As fish are among the most important products for human nutrition, sea food has received considerable attention due to its high biological values (Pigott and Tucker, 1990). Fish contains hydrosoluble and liposoluble vitamins and are a valuable source of protein and n-3 highly unsaturated fatty acids (Uaury and Valenzuela 1992; Holland *et al*., 1993).

This work is a contribution to the chemical characterization (moisture, protein, fat and ash) of five fish species among the most representative and the most consumed in the Gulf of Gabès (Tunisia): the annular sea bream *Diplodus annularis*, the grass goby *Zosterisessor ophiocephalus*, the golden grey mullet *Liza aurata*, the false scad *Caranx rhonchus* and the bogue *Boops boops*. These fishes are consumed fresh, boiled in sauce, fried in oil, smoked and salted dried for a long conservation and they are available during all the year in the market, but with variable amounts.

We have also examined, in the present work, the factors influencing this chemical composition (size, sex, meat position and species) and investigated the possibility of distinguishing different groups of fish taking into account this global chemical composition.

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Table I. - Fish names and size.

Common name	Latin name	Minimal size: Si 1		Medium size: Si 2		Maximal size: Si 3	
		Weight (g)	Length (cm)	Weight (g)	Length (cm)	Weight (g)	Length (cm)
Annular sea bream (E1)	*Diplodus annularis*	20-33	12.1-12.5	35-40	12.4-13.2	42-60	13-14
Grass goby (E2)	*Zosterisessor ophiocephalus*	20-35	12.8-13.5	36-50	14.1-16.2	60-75	16.6 -18.1
Golden grey mullet (E3)	*Liza aurata*	48-61	18.7-20.3	88-113	21-24.5		
False scad (E4)	*Caranx ronchus*			80-90	20.4-22.2		
Bogue (E5)	*Boops boops*			55-80	17.8-19		

MATERIAL AND METHODS

Raw material and samples preparation

Five teleost species [*Diplodus annularis* Linnaeus, 1758 (Sparidae); *Zosterisessor ophiocephalus* Pallas, 1811 (Gobiidae); *Liza aurata* Risso, 1810 (Mugilidae); *Caranx rhonchus* Geoffroy Saint-Hilaire, 1817 (Carangidae) and *Boops boops* Linnaeus, 1758 (Sparidae)] were purchased from the local fish market of Sfax (south of Tunisia) between December 2005 and May 2006. In this period, all fish species are out of sexual activity except the goby. The fishes of a determined species were rapidly transported on ice to the laboratory for preparation to chemical analyses. The length and weight of the whole fish were measured in order to select homogenous samples (Tab. I). For each species, three sizes were distinguished (minimal, medium and maximal).

Several organs (liver, head, gonads and viscera) and muscles were dissected. Females and males were analysed separately because the species shows sexual dimorphism. Figure 1 shows the fish muscle divided into six parts (P1 → P6). Three laterodorsal parts (P1, P2 and P3) were obtained, where P1 is the part of meat near the head and P3 is the part of meat near the tail. Three lateroventral parts were also distinguished (P4, P5 and P6), where P4 is the part near the head and P6 is the part near the tail. Part 2 and part 5 are located in the middle of the body.

The five examined fish species were caught from the coast of the Gulf of Gabès (Fig. 2)

Each fish species has its own biological cycle. False scad reproduces in summer. Their first sexual maturity is reached for 17 cm size approximately (Ben Salem and Ktari, 1980). False scad eats small fishes and invertebrates (FAO, 1973).

Spawning of golden grey mullet is probably associated with sea water temperature. Sexual maturity is reached during the third year for the male and the fourth year for the female. Size at first sexual maturity is 21.58 cm, which corresponds approximately to 3 years (Bedoui *et al.*, 2002).

Annular sea bream reproduces from February to September. Its sexual maturity is reached after one year for a length of 8-10 cm. Both sexes are well distinguished but there are some cases of protandric hermaphrodism. Size at first sexual maturity is estimated for both sexes at 10.40 cm corresponding to an average age of approximately 1.5 year.

The bogue moves in groups and can be seen on the surface especially during the night. It reproduces in February-April in the Eastern Mediterranean, and April-May in the Western Mediterranean. It is an hermaphrodite fish, generally protogenic (FAO, 1973). Maturity is reached at one year for fish length of 13 cm in the Western Mediterranean. The young fishes are especially carnivorous and the adults are especially herbivorous. The laying of *Boops boops* of the gulf of Tunis extends from March to June (Anato and Ktari, 1983).

For the grass goby the period of reproduction occurs from February to May at the level of the Tunisian coasts. It is from March to May in the north of the Adriatic (Balestra *et al.*, 1989), from April to May in the estuary of Tuzlov and in July in Varna (Miller, 1986). The females carry out two

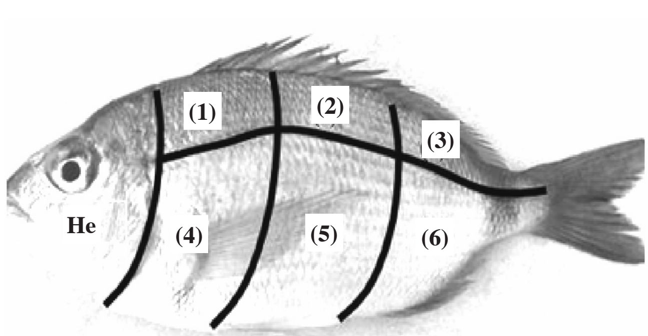

Figure 1. - Different parts of fish muscle. (1), (2), (3): laterodorsal parts. (4), (5), (6): lateroventral part.

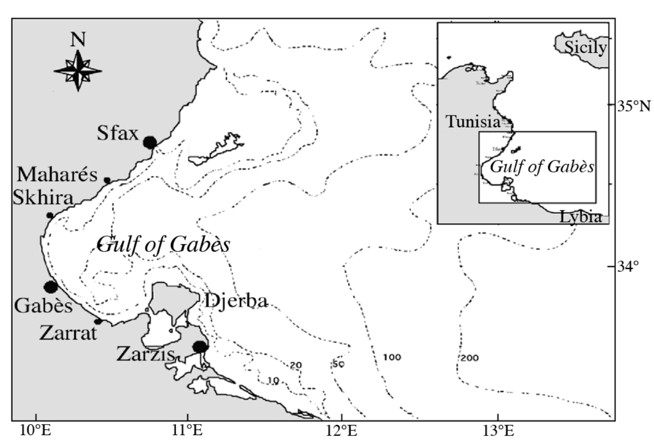

Figure 2. - Map of the Gulf of Gabès.

annual laying (Ota *et al*., 1996). The size of *Zosterisessor ophiocephalus* at the first sexual maturity is equal to 10.21 cm for females and to 11.25 cm for males.

Determination of the gonadosomatic and hepatosomatic indexes

The gonadosomatic index GSI was calculated as follows:

$$GSI : (W_g / W_{ev}) \times 100,$$

where W_g = gonad weight; W_{ev} = eviscerated fish weight.

The hepatosomatic index HSI was calculated as follows:

$$HSI : (W_h / W_{ev}) \times 100,$$

where W_h = liver weight; W_{ev} = eviscerated fish weight.

The GSI allows distinguishing the various stages of fish sexual cycle. Whereas, a high HSI indicates an important fat storage in liver.

The viscerosomatic index (VSI) was calculated as follows:

$$VSI : (W_v / W_{ev}) \times 100,$$

where W_V = viscera weight; W_{ev} = eviscerated fish weight.

Global chemical analysis

Chemical analyses were performed according to the AOAC (1984). Moisture content was measured by samples dehydration (in an oven at 105°C to a constant weight (48 h). The weight of the samples was determined by using a precision scale 10^{-4} g (Sauter).

The moisture analysis was repeated 6 to 11 times. Fat, protein and ash measurements were repeated three times (by using 3 fishes) at first; the variability between samples was ≤ 5%. For the next analysis ten dry samples were crushed by a Moulinex® blender. The fish dry powder of n (6 to 11) meat parts or organs was divided into 3 parts (m_1, m_2 and m_3) to determine the protein, fat and ash contents. All chemical analyses were expressed in wet basis (g/100 g of fresh fish).

Crude protein was determined from nitrogen content (N x 6.25) measured by using the Kjeldahl method (FAO, 1977). This method is based on digesting 0.2 g of dry sample by 10 ml of sulfuric acid. Fat was extracted by Soxhlet apparatus using chloroform as a solvent. An amount of 3 g of dry samples was extracted by 120 ml of chloroform for every extraction. Ash was determined by incinerating 0.5 g of dry sample at 550°C for 4 hours until constant weight.

Moisture, protein, fat and ash analysis were performed for the six meat parts of the fish muscles (P1 → P6) and the head. Only moisture content was measured for the organs (gonads, viscera and liver) because the available product quantity was not enough to measure protein, fat and ash contents.

Statistical analysis

Moisture, protein, fat and ash contents are presented as mean values, MV, (g/100 g fresh fish) ± error deviation (ED). The coefficient of variation (CV) is calculated as follows:

$$CV = (ED / MV) \times 100$$

The standard error of repeatability SER is calculated as follows:

$$SER = \sqrt{\frac{\sum (MV - \overline{MV})^2}{n-1}},$$

where MV = mean value; $\overline{MV}$ = arithmetic average value and n = number of samples.

All statistical analysis were performed by using SPSS software® version 13.0 (Statistical Package for Social Sciences). Three statistical treatments have been performed on experimental data:

- In order to know the main factors of variation; an analysis of variance was performed for moisture, protein, fat and ash contents measured in the six meat parts of the muscle and for moisture content measured in the fish organs according to the factors sex, size, meat parts and fish species.
- Correlation matrixes were established between different component contents (moisture, protein, fat and ash) measured in the six meat parts of the muscle.
- Discriminant analysis was applied to moisture, protein, fat and ash contents measured in the muscles of the different fish species. The object of this analysis was to gather the examined fishes in homogeneous groups according to their proximate chemical composition.

Every factor presenting a p-value (p) inferior to 0.05 was considered significant.

	GSI MV ± ED		VSI MV ± ED		HSI MV ± ED	
Species	Ma	Fe	Ma	Fe	Ma	Fe
E1	0.80 ± 0.05	0.50 ± 0.09	7.61 ± 1.30	7.04 ± 1	0.73 ± 0.08	1.84 ± 0.14
E2	1.16 ± 0.19	19.53 ± 2.30	3.53 ± 0.84	2.82 ± 0.6	4.02 ± 1.20	4.59 ± 1.02
E3	0.1 ± 0.01	0.31 ± 0.16	9.58 ± 1.36	8.74 ± 0.73	2.57 ± 0.55	1.90 ± 0.34
E4	0.16 ± 0.02	0.94 ± 0.11	2.67 ± 0.25	2.89 ± 0.46	0.60 ± 0.09	0.87 ± 0.27
E5	-	0.91 ± 0.19	-	5.21 ± 1.12	-	0.68 ± 0.14

Table II. - Gonadosomatic, viscerosomatic and hepatosomatic indexes (GSI, VSI and HSI) of the five species. Species named in table I. (MV ± ED: Mean value ± error deviation).

Table III. - Global chemical composition (g/100 g of fresh weight) of the studied parts of species medium size. Species named in table I. (MV ± ED: Mean value ± error deviation).

Species	Parts	Moisture (MV ± ED)	Protein (MV ± ED)	Fat (MV ± ED)	Ash (MV ± ED)
E1 Females n = 8	P1	73.61 ± 1.19	20.32 ± 0.30	2.46 ± 0.15	3.66 ± 0.01
	P2	71.61 ± 1.22	20.89 ± 0.30	2.98 ± 0.15	3.86 ± 0.06
	P3	72.82 ± 0.77	20.50 ± 0.30	3.55 ± 0.15	3.56 ± 0.01
	P4	67.05 ± 1.86	20.55 ± 0.30	9.04 ± 0.15	4.32 ± 0.06
	P5	64.44 ± 1.72	20.89 ± 0.30	8.57 ± 0.15	4.36 ± 0.06
	P6	72.03 ± 0.92	21.28 ± 0.30	3.95 ± 0.15	4.16 ± 0.06
E1 Males n = 8	P1	74.63 ± 0.91	19.80 ± 0.25	2.98 ± 0.15	3.28 ± 0.09
	P2	73.91 ± 1.24	19.81 ± 0.25	3.26 ± 0.15	3.21 ± 0.09
	P3	74.02 ± 0.41	19.88 ± 0.25	2.98 ± 0.15	3.55 ± 0.09
	P4	66.01 ± 1.05	20.77 ± 0.25	7.09 ± 0.15	6.72 ± 0.09
	P5	67.70 ± 1.56	20.00 ± 0.25	8.63 ± 0.15	4.42 ± 0.09
	P6	71.14 ± 1.09	20.32 ± 0.25	3.85 ± 0.15	4.97 ± 0.09
E2 Females n = 9	P1	78.82 ± 0.78	17.78 ± 0.30	1.10 ± 0.15	1.73 ± 0.06
	P2	78.49 ± 0.82	18.36 ± 0.30	0.93 ± 0.15	1.92 ± 0.06
	P3	78.03 ± 0.71	18.22 ± 0.30	1.79 ± 0.15	1.84 ± 0.06
	P4	77.95 ± 0.91	16.79 ± 0.30	1.03 ± 0.15	3.91 ± 0.06
	P5	79.35 ± 0.85	17.52 ± 0.30	0.83 ± 0.15	1.65 ± 0.06
	P6	78.12 ± 0.78	18.44 ± 0.30	0.80 ± 0.15	1.96 ± 0.06
E2 Males n = 11	P1	79.01 ± 0.95	18.00 ± 0.25	0.75 ± 0.15	1.36 ± 0.09
	P2	78.85 ± 0.70	17.97 ± 0.25	0.74 ± 0.15	1.53 ± 0.09
	P3	78.53 ± 0.94	18.00 ± 0.25	0.76 ± 0.15	1.94 ± 0.09
	P4	78.18 ± 0.59	17.82 ± 0.25	1.30 ± 0.15	2.90 ± 0.09
	P5	79.13 ± 0.81	18.74 ± 0.25	1.06 ± 0.15	1.55 ± 0.09
	P6	78.41 ± 0.79	19.16 ± 0.25	0.89 ± 0.15	1.90 ± 0.09
E3 Females n = 7	P1	77.00 ± 1.16	19.36 ± 0.30	1.58 ± 0.15	2.16 ± 0.06
	P2	76.83 ± 0.92	20.61 ± 0.30	1.37 ± 0.15	2.87 ± 0.06
	P3	76.15 ± 0.85	19.91 ± 0.30	1.43 ± 0.15	3.33 ± 0.06
	P4	74.83 ± 1.50	21.95 ± 0.30	2.12 ± 0.15	3.36 ± 0.06
	P5	76.28 ± 1.48	20.19 ± 0.30	1.87 ± 0.15	2.90 ± 0.06
	P6	75.97 ± 1.14	20.40 ± 0.30	1.51 ± 0.15	3.22 ± 0.06
E3 Males n = 6	P1	74.72 ± 1.62	21.27 ± 0.25	1.09 ± 0.15	2.39 ± 0.09
	P2	74.57 ± 1.54	20.99 ± 0.25	1.12 ± 0.15	2.79 ± 0.09
	P3	74.78 ± 1.25	21.46 ± 0.25	1.37 ± 0.15	2.73 ± 0.09
	P4	70.14 ± 2.30	20.94 ± 0.25	2.64 ± 0.15	4.90 ± 0.09
	P5	72.41 ± 2.71	22.62 ± 0.25	2.35 ± 0.15	2.38 ± 0.09
	P6	74.07 ± 1.62	21.90 ± 0.25	1.36 ± 0.15	2.75 ± 0.09
E4 Females n = 8	P1	78.98 ± 1.17	17.56 ± 0.30	1.03 ± 0.15	1.85 ± 0.06
	P2	78.74 ± 0.75	18.92 ± 0.30	2.61 ± 0.15	1.65 ± 0.06
	P3	75.67 ± 1.17	20.98 ± 0.30	3.04 ± 0.15	3.07 ± 0.06
	P4	76.34 ± 1.34	19.28 ± 0.30	1.66 ± 0.15	3.80 ± 0.06
	P5	78.10 ± 1.37	18.47 ± 0.30	1.33 ± 0.15	1.82 ± 0.06
	P6	76.14 ± 1.29	21.49 ± 0.30	1.19 ± 0.15	2.35 ± 0.06
E4 Males n = 7	P1	76.80 ± 1.05	18.60 ± 0.25	2.62 ± 0.15	1.19 ± 0.09
	P2	76.27 ± 1.29	19.65 ± 0.25	2.35 ± 0.15	1.13 ± 0.09
	P3	75.46 ± 1.11	20.25 ± 0.25	2.41 ± 0.15	1.96 ± 0.09
	P4	74.32 ± 1.04	19.00 ± 0.25	4.53 ± 0.15	1.88 ± 0.09
	P5	75.63 ± 1.23	19.94 ± 0.25	3.15 ± 0.15	1.23 ± 0.09
	P6	74.49 ± 1.39	22.11 ± 0.25	2.52 ± 0.15	1.42 ± 0.09
E5 Females n = 11	P1	75.70 ± 1.16	18.28 ± 0.30	2.99 ± 0.15	2.41 ± 0.06
	P2	75.50 ± 1.18	18.69 ± 0.30	2.49 ± 0.15	2.36 ± 0.06
	P3	74.82 ± 0.90	19.13 ± 0.30	2.65 ± 0.15	2.72 ± 0.06
	P4	71.36 ± 1.63	16.76 ± 0.30	6.61 ± 0.15	4.41 ± 0.06
	P5	73.94 ± 1.31	18.70 ± 0.30	5.41 ± 0.15	2.85 ± 0.06
	P6	74.79 ± 1.31	18.95 ± 0.30	3.13 ± 0.15	2.52 ± 0.06

RESULTS

The values of gonadosomatic, viscerosomatic and hepatosomatic indexes are presented in table II. The gonadosomatic indexes of annular sea bream (E1), golden grey mullet (E3), false scad (E4) and bogue (E5) were lower than 1%. The females of grass goby (E2) had an index value of about 19.53 ± 2.30%. So the examined fish species were on rest sexual activity except the grass goby, which was on sexual activity. The hepatosomatic index of the grass goby was high: about 4.30 ± 0.28%. So the fat was stored in the grass goby liver. For the viscerosomatic indexes, the golden grey mullet showed the highest value for males and females, respectively 9.58 ± 1.36% and 8.74 ± 0.73%. Female grass goby presented the lowest value of viscerosomatic index (2.82 ± 0.6%).

Repeatability of measurements

The mean values, the standard error of repeatability and the corresponding coefficients of variations of moisture, protein, fat and ash contents measurements (g/100 g of fresh fish) were determined for the muscles and the different organs. The values of the coefficient of variation of all measurements were inferior to 5%.

Chemical composition of the muscle

Table III shows the chemical composition of five species of medium size for different sexes, muscles parts and fish species. The highest moisture content was located in part 5 of grass goby female (79.35 ± 0.85%). The protein content of the different parts of the muscle was high (from 16.79 to 22.62%). The annular sea bream parts were fatter than the other ones. The ash content varied from 2.01 ± 0.68 g/100 g fresh fish (grass goby) to 4.17 ± 0.91 g/100 g fresh fish (annular sea bream), when taking into account males and females and the six meat parts. The highest ash content (6.72%) was obtained for P4 the meat parts of the annular sea bream male.

The comparison of the chemical composition of annular sea bream according to sex revealed that females were fatter but males were richer in moisture and ash.

For the grass goby, the males and the females showed the same order of variation in the global chemical composition. The males of false scad were richer in fat than females and were less hydrated.

The proximate chemical composition (average values determined on the six meat parts of males and

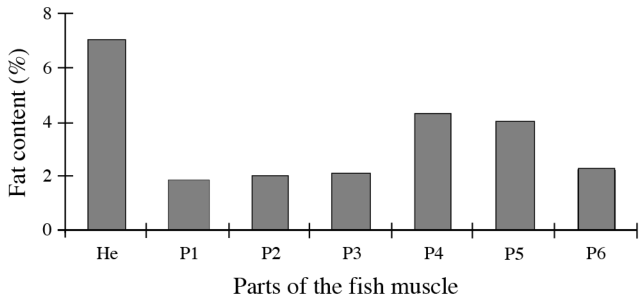

Figure 3. - Fat content of the head and the six meat parts of the muscle (sex, size and species are confounded) (He: head, P1 to P6: meat parts of the muscle).

females) of the fish muscles showed a high nutritional value. In fact, protein content varied from 18.06 ± 0.57 g/100 g fresh fish (grass goby) to 20.96 ± 0.56 g/100 g fresh fish (golden grey mullet). The fat content ranged from a low content (0.99 ± 0.08%) for grass goby to a medium content (4.94 ± 0.14%) for annular sea bream.

Distribution of fat content in the body

Figure 3 shows the average fat content of the six parts of the muscles and the head (sexes, sizes and fish species are confounded). An anteroposterior gradient of fat content decreasing from the head (≈ 7%) to part 6 of the meat muscle

Table IV. - Moisture content of organs according to fish species and sex. Species names in table I.

Organs	Species	Sexes	Mean values	Standard deviation	Minimal level	Maximal level
Liver	E1	Females	71.00	2.60	65.65	76.50
		Males	71.85	4.50	62.45	81.20
	E2	Females	38.50	3.20	31.80	45.20
		Males	36.50	3.25	29.70	43.30
	E3	Females	74.00	3.20	67.35	80.80
		Males	76.65	4.50	67.30	86.05
	E4	Females	75.30	4.50	65.90	84.65
		Males	73.60	4.50	64.20	83.00
	E5	Females	72.10	4.50	62.70	81.50
		Males	-	-	-	-
Gonad	E1	Females	77	2.60	71.55	82.40
		Males	75.25	4.50	65.85	84.60
	E2	Females	71.70	3.20	64.95	78.40
		Males	72.90	3.20	66.10	79.70
	E3	Females	78.50	3.20	71.80	85.25
		Males	82.15	4.50	72.75	91.55
	E4	Females	77.85	4.50	68.50	87.25
		Males	71.20	4.50	61.80	80.55
	E5	Females	80.75	4.50	71.35	90.10
		Males	-	-	-	-
Head	E1	Females	64.40	2.60	59.00	69.90
		Males	65.40	4.50	56.00	74.80
	E2	Females	76.45	3.20	69.70	83.20
		Males	75.90	3.25	69.10	82.70
	E3	Females	66.20	3.20	59.45	72.90
		Males	73.60	4.50	64.20	82.95
	E4	Females	75.00	4.50	65.60	84.40
		Males	71.65	4.50	62.25	81.00
	E5	Females	71	4.50	61.60	80.35
		Males	-	-	-	-
Viscera	E1	Females	60	2.60	54.55	65.40
		Males	73.50	4.50	64.10	82.90
	E2	Females	77.35	3.20	70.65	84.10
		Males	78.50	3.25	71.70	85.30
	E3	Females	73.65	3.20	66.95	80.40
		Males	79.90	4.50	70.50	89.25
	E4	Females	80.50	4.50	71.10	89.85
		Males	72.70	4.50	63.30	82.05
	E5	Females	80.30	4.50	70.90	89.70
		Males	-	-	-	-

was observed. So the lateroventral muscle parts were fatter (≈ 3.05%) than the laterodorsal (≈ 2.70%) meat parts (P1, P2 and P3).

Variation of moisture content of the organs

The mean values of moisture content of the organs are presented in table IV. Moisture content of the liver varied between 71 to 76.65 g/100 g fresh fish, according to the species, except for the liver of grass goby which showed the lowest moisture content (36.50 g/100 g fresh fish for males and 38.50 g/100 g of fresh fish for females). The gonads of bogue were the moistest organs (≈ 80.75 g/100 g fresh fish).

The head of annular sea bream was the least humid. Its moisture content varied from 64.40 g/100 g fresh fish for males to 65.40 g/100 g fresh fish for females. The head of grass goby was the most humid. Its moisture content varied between 69.10 to 83.20 g/100 g of fresh fish. Annular sea bream viscera had the highest fat content and the lowest moisture content.

The variance analysis of moisture content according to size, sexes, organs and species is presented in the first line of table V. Every factor presenting a p-value (p) inferior to 0.05 was considered significant. Moisture content varied significantly according to organs ($p < 0.001$), fish species ($p < 0.001$) and the interaction between both factors ($p < 0.001$). Size and sex did not have any significant effect on the variation of the organs moisture content ($p = 0.44$ for the size and $p = 0.41$ for the sexes).

The variance analysis of moisture, protein, fat and ash contents according to size, sexes, parts and fish species presented in table V shows that moisture, protein, fat and ash contents varied significantly according to meat parts, fish species ($p < 0.001$). For the interaction between both factors, moisture and fat contents varied significantly ($p < 0.001$). Whereas size and sexes had no significant effect on this variation; except for fat content, on which size had a significant effect ($p < 0.001$).

Correlation between different chemical components

Correlation matrixes between moisture, protein, fat and ash contents of the six meat parts of the muscles (for all species confounded and for each fish species) are presented in table VI, where R is the coefficient of correlation and p is the p-value. There is negative correlations for "fat-moisture", "protein-ash" and "moisture-ash" contents and a positive correlation for "fat-ash" contents. Significant correlations (at 95%) are "fat-moisture" ($p < 10^{-3}$ and $R = -0.85$) and "ash-moisture" ($p < 10^{-3}$ and $R = -0.646$).

The matrixes of correlations between the different analysed compounds were also established for each species separately to check if the same type of correlation was kept and if the values of the statistical parameters (R and p) were improved. Indeed, if the correlation type was not the same for all species, the intensity of the correlations determined for all fishes could be affected.

The statistical parameters (correlation coefficient, R and p values) were clearly improved if each species was examined separately (R increases and p decreases). On the other hand, the intensity of the correlations varied according to the species. Indeed, some species showed strong correlations "fat-moisture" such as bogue (E5), golden grey mullet (E3), false scad (E4) and annular sea bream (E1). The grass goby (E2) showed insignificant "fat-moisture" correlation. Furthermore, for "fat-moisture", "fat-protein", "ash-moisture", "ash-protein" and "ash-fat" contents, the correlation

Table V. - Variance analysis of moisture content according to the factors organs, sexes, species and size and of moisture, protein, fat and ash contents according to the factors parts, sexes, species and size of the fishes (HS = highly significant, $p < 0.01$; NS = not significant, $p > 0.05$; S = significant, $p < 0.05$).

Factors		F (Fisher number)	p (p-value)	Significance level
Moisture	Size	0.59	0.44	NS
	Sexes	0.69	0.41	NS
	Organs	12.57	$<10^{-3}$	HS
	Species	11.19	$<10^{-3}$	HS
	Organs × species	16.51	$<10^{-3}$	HS
Sexes	Moisture	4.24	0.04	S
	Protein	3.16	0.08	NS
	Fat	0.02	0.88	NS
	Ash	3.59	0.06	HS
Size	Moisture	0.1	0.75	NS
	Protein	8.65	0.005	S
	Fat	15.15	$<10^{-3}$	HS
	Ash	5.43	0.02	S
Species	Moisture	90.18	$<10^{-3}$	HS
	Protein	11.11	$<10^{-3}$	HS
	Fat	29.06	$<10^{-3}$	HS
	Ash	34.54	$<10^{-3}$	HS
Meat parts	Moisture	14.06	$<10^{-3}$	HS
	Protein	14.62	$<10^{-3}$	HS
	Fat	17.13	$<10^{-3}$	HS
	Ash	67.45	$<10^{-3}$	HS
Species × parts	Moisture	2.87	$<10^{-3}$	HS
	Protein	0.78	0.74	NS
	Fat	3.34	$<10^{-3}$	HS
	Ash	1.05	0.42	NS

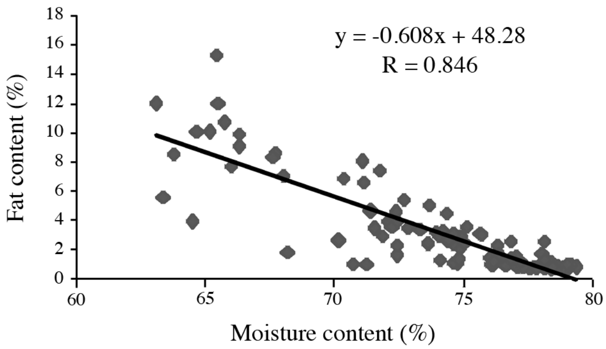

Figure 4. - Relationship between fat and moisture contents for all species (parts of muscle and head confounded) .

was the same when species were examined together or separately. The correlation was positive for “ash-fat” and negative for the others.

Besides, “protein-moisture” correlation which was negative and insignificant in the global correlation matrix became positive and significant for some fishes. The correlation type, “protein-moisture” varied according to the species examined. This correlation was significant for *Boops boops*, *Zosterisessor ophiocephalus* and *Liza aurata* ($p < 0.05$) and it was insignificant for *Caranx rhonchus* and *Diplodus annularis*. The “fat-moisture” correlation was significant for all species and it was the strongest one for the majority of the species (annular sea bream, golden grey mullet, false scad, bogue) and also for all species when analysed together. Figure 4 shows the relationship between fat and moisture contents (g/100 g fresh weight) for all species (parts of muscle and head confounded). The expression of the last correlation is:

Fat content = - 0.61 × Moisture content + 47.28; R = - 0.85; $p < 10^{-3}$, n = 98.

Discriminant analysis of the analysed chemical contents

Figure 5 shows two axes: axis 1 presents the correlation moisture (R = +0.83) - fat (R = -0.43) and axis 2 presents the correlation protein (R = +0.37) - ash (R = +0.38). The presence of a moisture-fat axis confirmed the previous results of correlation matrixes showing that fat-moisture correlation was the most significant.

Axis 1 separates the grass goby (a lean fish) from the annular sea bream (a fatty fish) fish. Grass goby presents a high content of moisture and is located at the right side of axis 1. Annular sea bream presents a high content of fat and is located at the left side of axis 1. On axis 2, all the species overlap except the false scad, which is located at the top of axis 2, corresponding to fishes having a higher protein content.

Thus, the discriminant analysis allowed separating in space three fish groups according to their global chemical composition:

- fish with a low fat muscle content with higher content of moisture, such as the grass goby;
- the fat fish such as annular sea bream and golden grey mullet;
- fish with a high muscle protein content such as the false scad.

DISCUSSION

The results of the global chemical compositions of fish muscles (Tab. III, IV) are in agreement with the data reported in the literature (Stansby, 1962). According to Bougis (1952), the thin fish, belonging to the *Gadus* type, store some fat reserves in their liver to be ready for reproduction. The value of hepatosomatic index of the grass goby is high (4.6%), indicating that the fat is stored in the liver (44.04%). During the maturation of the sexual products, these fish use their proteins content from the muscles and fat content from the liver. This result is in accordance with the literature; in fact, the chemical composition of the fish is extremely related to their sexual cycle (Kozlova, 1997; Abdelmouleh, 1997). The period preceding the laying is characterized by the accumulation of nonlipidic reserves in the muscles especially the proteins. The fish belonging to the *Mullus* type store the fat in the muscle. Annular sea bream is a particular example for the storage of fat in the muscle. During the

Table VI. - Correlation matrixes of moisture, protein, fat and ashes contents of the muscle established for each fish species and all fish species confounded. Species names in table I. A: ash; F: fat; M: moisture; p: p value determined at 95% of significance, significant for $p < 0.05$; P: protein; R: correlation coefficient).

Correlation	Species										All species confounded	
	E1, n = 28		E2, n = 28		E3, n = 21		E4, n = 14		E5, n = 7		n = 98	
	R	p	R	p	R	p	R	p	R	p	R	p
P-M	0.13	0.50	0.42	0.02	0.56	0.01	0.17	0.56	0.78	0.04	-0.11	0.26
F-M	-0.75	$< 10^{-3}$	-0.29	0.14	-0.89	$< 10^{-3}$	-0.78	0.001	-0.97	$< 10^{-3}$	-0.83	$< 10^{-3}$
F-P	-0.61	$< 10^{-3}$	-0.04	0.83	-0.79	$< 10^{-3}$	-0.57	0.03	-0 .86	0.01	-0.26	0.009
A-M	-0.62	$< 10^{-3}$	-0.8	$< 10^{-3}$	-0.7	$< 10^{-3}$	-0.45	0.10	-0.90	0.006	-0.64	$< 10^{-3}$
A-P	-0.54	0.00 3	-0.57	$< 10^{-3}$	-0.75	$< 10^{-3}$	-0.75	0.002	-0.96	0.001	-0.38	$< 10^{-3}$
A-F	0.79	$< 10^{-3}$	0.23	0.24	0.72	$< 10^{-3}$	0.54	0.04	0.93	0.003	0.67	$< 10^{-3}$

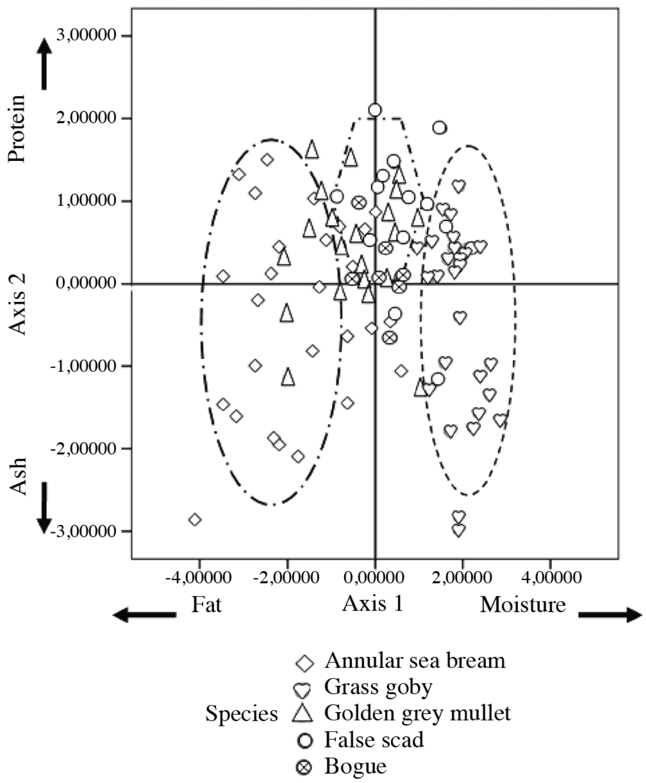

Figure 5. - Discriminant analysis of moisture, protein, fat and ash contents of muscles.

sexual activity, period corresponding to a low level of feeding, the fish shows a high gonadosomatic index and a low viscerosomatic one.

According to the classification of fishes (Boyer *et al*., 1995) based on their fat content, golden grey mullet and false scad could be considered as a medium-fat fish category ≈ 2.5% (g fat/100 g fresh fish), whereas annular sea bream and bogue could be considered as fat fish categories ≈ 5 to 25% (g fat/100 g fresh fish) and grass goby as a lean fish ≈ 1%. The lowest amounts of protein, fat and ash were found in the goby fish. The goby is the thinnest among the analysed fishes and it could be recommended to people being on a light diet. This fish classification is in agreement with the result of discriminate analysis (Fig. 5).

The lateroventral parts of the muscle are fatter than the laterodorsal meat parts (Fig. 3). This result is in agreement with what has been mentioned by Thakur *et al*. (2002) for cultured yellowtail (*Seriola quinqueradiata*). The fat and moisture content gradients observed throughout the fish body are in agreement with the result obtained by Date and Yamamoto (1988) and by Abdelmouleh (1997). The authors reported a higher moisture content of the caudal muscle. The ventral parts of the meat muscle (P4 and P5) present the highest fat contents (Tab. III). This result is also in agreement with the observations of Bell *et al*. (1998) which indicate that in farmed Atlantic salmon (*Salmo salar*) the highest fat level is in the region located immediately in front of the dorsal fin while the lowest one is localized in the tail region.

The factors influencing the moisture content shown to be significant in this present work for all the studied fish species are organs, meat parts location and species. However, sex and size have no significant effect on global chemical composition of the examined fishes.

The mean values of moisture content measured in fish organs (Tab. IV) are in accordance with the analysis of fat content, which indicates that grass goby is the less fatty fish and that the fat reserves are stored in the liver as reported by Boyer *et al*. (1995).

The fish species (annular sea bream, golden grey mullet, false scad and bogue) muscle composition analysed by correlation matrix showed a strong "fat –moisture" correlation, and a strong "protein-ash" correlation (Tab. VI). The negative correlation between fat and moisture contents is largely known in the literature (Kizevetter, 1973; Pérez-Villareal and Pozo, 1990; Méndez and González, 1997; Grigorakis *et al*., 2002). This correlation could be explained by the hydrophobic character of fat. Indeed, the fat content is always concentrated in less hydrated tissues.

Discriminant analysis separates three groups (Fig. 5), a finding in agreement with the results of the correlation matrices.

Marine food is able to provide the human organism with cellular maintenance and essential building materials. The muscle of thin fish, such as the goby, has an energy value slightly lower than that of beef but it is more digestible (Sainclivier, 1983). The energy given by fatty fish as the annular sea bream is equivalent to that of the meat of mammal, but it has the advantage of containing a greater quantity of iodine and liposoluble vitamins, especially vitamins D which misses in human food (Sainclivier, 1983). The low content of conjunctive tissue and the short length of muscle fibres facilitate the hydrolysis of fish proteins. Consequently the examined fish could be recommended for human nutrition. The high-nutritional value of annular sea bream, grass goby, golden grey mullet, false scad and bogue (low fat content and high proteins content) makes these species highly suitable for commercial exploitation. However, the exploitation of these species should be carefully managed according to the assessment of the overall impact of the coastal catch fish species of the Gulf of Gabès.

CONCLUSION

The variation of the global chemical composition (moisture, protein, fat and ash) of five species of the coastal catch fishes of the gulf of Gabès (annular sea bream, grass goby, golden grey mullet, false scad and bogue) is significant according to species and parts of the muscles or organs. The

anteroposterior gradient of fat content, decreasing from head to tail, was observed throughout the examined fish body. The lateroventral meat parts of the muscle are fatter than the laterodorsal ones. A negative correlation between moisture and fat contents was observed for all fish species whatever the meat location.

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REFERENCES

ABDELMOULEH A., 1997. - Étude expérimentale de la valorisation de l'allache *Sardinella aurit*a et de la seiche *Sepia officinalis* en Tunisie. PhD Thesis, 179 p. Univ. Sfax, Tunisia.

ANATO C.B. & KTARI M.H., 1983. - Reproduction de *Boops boops* (Linné, 1758) et de *Sarpa salpa* (Linné, 1758), Poissons Téléostéens, Sparidae du golfe de Tunis. *Bull. Inst. Natl. Sci. Tech. Océanogr. Pêche Salammbô*, 10: 49-53.

AOAC, 1984. - Official Methods of Analysis. pp. 330-352. Washington, DC: Association of official Analytical Chemists.

BALESTRA M., FERRERO E.A., GIULIANINI P.G., MARZARI R., OTA D. & PATZNER R., 1989. - Preliminary identification of yolk proteins as molecular markers of ovarian maturation in *Zosterisessor ophiocephalus* (Pisces: Gobiidae). *Aquacult. Eur.'89, Bordeaux, Nov. Thalassia 10,* Suppl. 1: 627-629.

BEDOUI R., GHARBI H. & EL ABED A., 2002. - Périodes de reproduction et maturité sexuelle de *Liza aurata* (Poisson, Mugilidae) des côtes est et sud tunisiennes. *Bull. Inst. Natl. Sci. Tech. Mer Salammbô,* 29: 11-15.

BELL J.G., MCEVOY J., JOHN L.W., MCGHEE F., MILLAR R.M. & JOHN R.S., 1998. - Flesh lipid and carotenoid composition of Scottish farmed Atlantic salmon (*Salmo salar*). *J. Agric. Food Chem.*, 46: 119-127.

BEN SALEM M. & KTARI M.H., 1980. - Présentation des espèces du genre *Trachurus* Rafinesque, 1810 et *Caranx* Lacépède, 1801 (Poissons, Téléostéens, Carangidae). *Bull. Off. Natl. Pêch., Tunisie*, 4(1): 155-168.

BOUGIS P., 1952. - Recherches biométriques sur les rougets (*Mullus barbatus*, *Mullus surmelutus*). *Arch. Zool. Exp. Gén.*, 89(2): 57-174.

BOYER J., FRENTZ J., MICHAUD C. & AUBERT H., 1995. - La Charcuterie de Poisson et des Fruits de Mer. pp. 35-40. MAE-ERTI éditeurs.

DATE K. & YAMAMOTO Y., 1988. - Seasonal variations with growth in nutritive components in meat of cultured yellowtail *Seriola quinqueradiata*. *Nippon Suisan Gakkaishi,* 54: 1041-1047.

DGPA, 2008. - Annuaire des statistiques des produits de la pêche. Direction générale de la pêche et de l'aquaculture, ministère de l'Agriculture de Tunisie.

FAO, 1973. - Fiches FAO d'Identification des Espèces pour les Besoins de la Pêche Méditerranée et Mer Noire. Projet GCP/INT/422/EEC, Rome, 2: 761-1530.

FAO, 1977. - Recueil de méthodes d'analyse et de techniques d'examen pour le contrôle de la qualité du poisson et des produits de la pêche. Programme de formation ACDI/FAO/COPACE. TF INT 180 (CAN). W/K 8136. 59 p.

GRIGORAKIS K., ALEXIS M.N., TAYLOR K.D.A. & HOLE M., 2002. - Comparison of wild and cultured gilthead sea bream (*Sparus aurata*); composition, appearance and seasonal variations. *Int. J. Food Sci. Technol.*, 37(5): 477-484.

HOLLAND B., BROWN J. & BUSS D.H., 1993. - Fish and fish products. In: Third Supplement to McCance and Widdowson's The Composition of Foods. 5th edit. Royal Society of Chemistry and Ministry of Agriculture, Fisheries and Food. London: HMSO.

KIZEVETTER I.V., 1973. - Chemistry and technology of Pacific fish. 304 p. Jerusalem: Israel Program for Scientific Translations.

KOZLOVA T.A., 1997. - Seasonal cycles in total chemical composition of two Lake Baikal benthic-pelagic sculpins (*Cottocomephorus*, Cottoidei). *J. Fish Biol.*, 50: 734-743.

MÉNDEZ E. & GONZÁLEZ M.R., 1997. - Seasonal changes in the chemical and lipid composition of fillets of the Southeast Atlantic hake (*Merluccius hubbsi*). *Food Chem.*, 59(2): 213-217.

MILLER P.J., 1986. - Gobioid. *In:* Fishes of the north-Eastern Atlantic and the Mediterranean (Whitehead P.J.P., Bauchot M.L., Hureau J.C., Nielson J. & Tortonese E., eds), pp. 1019-1085. Paris: Unesco.

OTA D., MARCHESAN M. & FERRERO E.A., 1996. - Sperm release behaviour and the fertilization in the grass goby. *J. Fish Biol.*, 49: 246-256.

PÉREZ-VILLAREAL B. & POZO R., 1990. - Chemical composition and ice spoilage of Albacore (*Thunnus alalunga*). *J. Food Sci.*, 55: 678-682.

PIGOTT G.M. & TUCKER B.W., 1990. - Seafood: Effects of Technology on Nutrition. 384 p. New York: Marcel Dekker Inc.

SAINCLIVIER M., 1983. - L'Industrie alimentaire halieutique. Tome 1 : Le Poisson Matière première. 263 p. Bulletin Scientifique et Technique de l'ENSA et du CCR (Rennes).

STANSBY M.E., 1962. - Proximate composition of fish. *In*: Fish in Nutrition (Heen E. & Kreuzer.R., eds), pp. 55-60. London: Fishing News Books Ltd.

THAKUR D.P., MORIOKA K., ITOH Y. & OBATAKE A., 2002. - Influence of muscle biochemical constituents on the meat texture of cultured yellowtail (*Seriola quinqueradiata*) at different anatomical locations. *J. Sci. Food Agric.*, 82: 1541-1550.

UAURY R. & VALENZUELA A., 1992. - Marine oils as a source of omega-3 fatty acids in the diet: how to optimize the health benefits. *Prog. Food Nutr. Sci.*, 16: 199-243.

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